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WORK IN HOT ENVIRONMENTS

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PREFACE

This publication provides employers and workers with information about how the body responds to heat and how heat exposure is evaluated and controlled.

"Heat stress" is used by some workers to describe the response of the body to excess heat. Others use heat stress to describe a hot environment. To avoid confusion, "heat stress" is not used at all in this document.

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1. INTRODUCTION

Most people feel comfortable when the air temperature is between 20 and 27°C and the relative humidity ranges from 35 to 60%. When air temperature or humidity is higher, people feel uncomfortable. Such situations do not cause harm as long as the body can adjust to cope with the additional heat. Very hot environments can overcome the body's coping mechanisms, leading to a variety of serious and possibly fatal conditions.

Workplace conditions can lead to harmful heat burdens. In foundries, steel mills, bakeries, smelters, glass factories, and furnaces, extremely hot or molten material is the main source of heat. Outdoor occupations, such as construction, road repair, open-pit mining and agriculture, expose workers to summer sunshine. In laundries, restaurant kitchens, and canneries, high humidity adds to the heat burden. In all instances, the result may be a working environment which can potentially overcome the body's ability to deal with heat.

2. HOT ENVIRONMENTS AND THE HUMAN BODY

The healthy body maintains its internal temperature around 37°C. Variations, usually of less than 1°C, occur with the time of day, level of physical activity or emotional state. A change of body temperature exceeding 1°C occurs only during illness or when environmental conditions surpass the body's ability to cope with extreme temperatures.

As the environment warms, the body's internal "thermostat" adjusts by pumping more blood to the skin and by increasing sweat production. In this way the body increases the rate of heat loss to balance the heat burden created by the environment. When the rate of heat gain exceeds the rate of heat loss, body temperature begins to rise.

The main source of heat gain is the body's own internal heat. Called metabolic heat, it is generated within the body by the biochemical processes that keep us alive and by the energy we use in physical activity.

3. HEAT GAIN AND HEAT LOSS

The body exchanges heat with its surroundings mainly through radiation, convection, and evaporation of sweat.

Radiation is the process by which the body gains heat from surrounding hot objects, for example hot metal, furnaces or steam pipes, and loses heat to cold objects, such as chilled metallic surfaces, without contact with them. No radiant heat gain or loss occurs when the temperature of surrounding objects is about 35°C, the same temperature as skin.

Convection is the process by which the body exchanges heat with the surrounding air. The body gains heat from hot air and loses heat to cold air which is in contact with the skin. Convective heat exchange increases with increasing air speed and increased differences between air and skin temperature.

Evaporation of sweat from the skin cools the body. Evaporation proceeds more quickly and the cooling effect is more pronounced with high wind speeds and low relative humidity. Sweat also evaporates more quickly when there is a large difference between the skin and air temperatures.

The body also exchanges small amounts of heat by conduction and breathing. By conduction, the body gains or loses heat when it comes into direct contact with hot or cold objects. Breathing exchanges heat because the respiratory system warms inhaled air. When exhaled, this warmed air carries away some of the body's heat. However, the amount of heat exchanged through conduction and breathing is normally small enough to be ignored in assessing the heat load on the body.

4. EFFECTS OF HEAT

In moderately hot environments, the body goes to work to dissipate excess heat. The heart rate increases to pump more blood through outer body parts and skin so that excess heat is lost to the cooler environment, and sweating occurs. These changes impose additional demands on the body.

Changes in blood flow and excessive sweating reduce a person's ability to do physical and mental work. Manual work produces additional metabolic heat and adds to the heat burden. Performance of mental tasks deteriorates when the environmental temperature rises above 30°C.

Heat can lead to accidents, owing to slipperiness of sweaty palms and to accidental contact with hot surfaces. As a worker moves from a cold to a hot environment, fogging of eye glasses can briefly obscure vision, presenting a safety hazard.

Several studies comparing the heat tolerances of men and women have concluded that women are generally less heat tolerant than men. This difference seems to diminish when comparisons take into account cardiovascular fitness, body size and acclimatization.

Women have a lower sweat rate than men of equal fitness, size and acclimatization. Women may be more tolerant of heat under humid conditions, but less tolerant than men under dry conditions.

Illnesses Caused By Short-Term Heat Exposure

The risk of heat-related illness varies from person to person. Older and obese people are generally at high risk. Heat exposure causes the following illnesses.

Heat edema is swelling which generally occurs among people who are not acclimatized to working in hot conditions. Swelling is often most noticeable in the ankles. Recovery occurs after a day or two in a cool environment.

Heat rashes are tiny red spots on the skin. The sufferer feels a prickling sensation during heat exposure. The spots are the result of inflammation caused when the ducts of sweat glands become plugged.

Heat cramps are sharp pains in muscles. The cause is salt imbalance, resulting from the failure to replace salt lost with sweat. Cramps most often occur when workers drink large amounts of water without taking in sufficient salt.

Heat exhaustion is caused by failing to replace the body water and salt lost through excessive sweating. Signs and symptoms of heat exhaustion include weakness, dizziness, visual disturbances, intense thirst, nausea, headache, vomiting, diarrhea, muscle cramps, breathlessness, palpitations, tingling and numbness of the hands and feet. Recovery occurs after resting in a cool area and consuming cool salted drinks.

Heat syncope is heat-induced giddiness and fainting that occurs while a person is standing. It occurs mostly among unacclimatized people. It is caused by the loss of body fluids through sweating, and by lowered blood pressure, due to pooling of blood in the legs. Recovery is rapid after rest in a cool area.

Heat stroke and heat hyperpyrexia are the most serious heat illnesses. They are caused by prolonged work in hot environments. Signs of heat stroke include dry, hot skin (due to failure of sweating), body temperature often exceeding 41°C and complete or partial loss of consciousness. The signs of heat hyperpyrexia are similar except that the skin remains moist.

Heat stroke and heat hyperpyrexia require prompt medical attention. First aid should be given immediately. Delayed treatment may result in damage to the brain, kidneys and heart. Treatment may involve removal of the victim's clothing and spraying the body with cold water. Fanning increases evaporation and further cools the body. Immersing the victim in cold water more efficiently cools the body but it can result in harmful overcooling which can interfere with vital brain functions, so it must only be done under close medical supervision.

Lack of acclimatization, poor levels of physical fitness and pre-existing diarrhea or fever increase susceptibility to heat stroke and hyperpyrexia. Certain drugs such as tranquilizers and diuretics can also increase an individual's susceptibility.

Illnesses Caused By Long-Term Heat Exposure

Certain kidney, liver, heart, digestive system, central nervous system and skin illnesses are thought by some researchers to be linked to long-term heat exposure. But the evidence supporting these associations is not conclusive.

Chronic exhaustion, sleep disturbances and susceptibility to minor injuries and sicknesses have all been attributed to the effects of prolonged exposure to heat.

The lens of the eye is particularly vulnerable to radiation produced by red-hot metallic objects because it has no heat sensors and lacks blood vessels to carry heat away. Glass blowers and furnacemen have developed cataracts after many years of exposure to radiation from hot objects. Foundry workers, blacksmiths and oven operators are also exposed to possibly eye-damaging radiation.

A possible link between heat exposure and reproductive problems has been suggested. Data from laboratory experiments on animals have shown that heat stress may adversely affect the reproductive function of males and females. Exposure of males resulted in reduced rate of conception. Exposure of females caused disruption of the reproductive cycle until they became acclimatized to heat. When animals are simultaneously exposed to heat and toxic chemicals, the influence of heat exposure seems to accelerate the chemical reactivity.

In men, repeatedly raising testicular temperature 3 to 5°C decreases sperm counts. There is some evidence of reduced fertility among heat-exposed women, however the data are inconclusive. There are no adequate data from which conclusions can be drawn regarding the reproductive effects of occupational heat exposure at currently accepted exposure limits.

5. MEASUREMENT OF OCCUPATIONAL HEAT EXPOSURE

Various methods of measuring occupational heat exposure combine the environmental factors that contribute to heat load. The most commonly used measure is the wet bulb globe temperature.

The Wet Bulb Globe Temperature (WBGT)

The wet bulb globe temperature is calculated using a formula that takes into account air temperature and movement, radiant heat and evaporation.

Air temperature is measured simply using a conventional thermometer.

The contribution made by radiant heat is measured using a black globe thermometer. A conventional thermometer is inserted through a rubber stopper into a hollow, six-inch diameter copper ball. The thermometer bulb is positioned at the centre of the copper ball which is coated with a flat black paint. The black globe thermometer normally requires at least 20 minutes to come to equilibrium.

The cooling effect of evaporation and air movement is taken into account using a natural wet bulb thermometer. A natural wet bulb thermometer is a conventional thermometer with its bulb wrapped with an absorbent cotton wick. The wick extends 30 to 35 millimetres above the thermometer bulb, and the lower end of the wick is immersed in distilled water. About 25 mm of moistened wick is exposed between the water and the bulb of the thermometer. The moist wick continuously provides water for evaporation. As with the black globe thermometer, the natural wet bulb thermometer also requires at least 20 minutes to reach equilibrium.

Two different methods are used to calculate WBGT in the workplace: a) for workplaces with sunlight, b) without.

When conditions of the workplace fluctuate widely, time-weighted WBGT is often used. See Appendix A which gives worked examples of WBGT calculations.

WBGT direct reading meters, often called heat stress analyzers, are now available--with these no calculations are necessary.

Carrying out a detailed engineering assessment of heat requires additional measurements and calculations that are not required for WBGT measurement. More information is contained in the materials included in the Further Reading list.

6. EXPOSURE LIMITS

Exposure limits intended to minimize the risk of heat-related illnesses are set by provincial and territorial governments for most Canadian workplaces, and by Labour Canada for workplaces under the federal jurisdiction. The exposure limits for heat set by these agencies generally parallel the limits recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). The ACGIH recommendations are shown in Table 1.

The ACGIH exposure limits are intended to protect most workers from heat-related illnesses. The limits are higher than they would have been if they had been developed to deal with the issue of comfort. In addition, the ACGIH recommendations do not deal with the full range of occupational situations. Modifications to ACGIH recommendations that accommodate some of these situations are suggested in Table 2.

Table 1 - Threshold limit values (TLVs) for heat exposure recommended by the ACGIH

Work - Rest Regimen (each hour)	WBGT (°C) for Different Work Loads		
	Light	Moderate	Heavy
Continuous work	30.0	26.7	25.0
45 min. work - 15 min. rest	30.6	28.0	25.9
30 min. work - 30 min. rest	31.4	29.4	27.9
15 min. work - 45 min. rest	32.2	31.1	30.0

Examples of work loads:

Light work--sitting or standing to control machines, performing light hand or arm work
Moderate work--walking about with moderate lifting and pushing
Heavy work--pick and shovel work, digging

Adapted from: TLVs: threshold limit values for chemical substances and physical agents in the environment and biological exposure indices with intended changes for 1987-88. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists, 1987. p. 69.

Table 2 - Suggested modifications to the ACGIH TLVs for heat exposure (given in Table 1)

Condition		Suggested change in exposure limit °C
Unacclimatized worker		Subtract 2°C
Obese or elderly		Subtract 1 to 2°C
Female		Subtract 1°C
Air velocity over 1.5 m/s (5.4 km per hour)		Add 2°C
Clothing	- shorts	Add 2°C
	- body armour, impermeable jacket	Subtract 2°C
	- rain coat, fireman's coat, full length coat	Subtract 4°C
	- completely enclosed suit	Subtract 5°C

Adapted from: Elias, J.D. et al. Work practices for persons working in hot environments. Winnepeg, Manitoba: Manitoba Department of Environment and Workplace Safety and Health, Workplace Safety and Health Division, 1977.

7. CONTROL MEASURES

The risk of heat-related illnesses can be reduced by engineering controls to provide a cooler workplace, by safe work practices to reduce worker exposure, and by training employees to recognize and prevent heat illnesses. For a summary of these control measures, please see Appendix B.

Engineering Controls

Engineering controls are the most effective means of reducing excessive heat exposure. The examples which follow illustrate some engineering approaches to reducing heat exposure.

Reducing metabolic heat production. Automation and mechanization of tasks minimize the need for heavy physical work and the resulting buildup of body heat.

Reducing the radiant heat emission from hot surfaces. Covering hot surfaces with sheets of low emissivity material, such as aluminum or paint, reduces the amount of heat radiated into the workplace.

Insulating hot surfaces. Insulation reduces the heat exchange between the source of heat and the work environment.

Shielding. Shields stop radiated heat from reaching work stations. Two types of shields can be used. Stainless steel, aluminum or other bright metal surfaces reflect heat back towards the source. Absorbent shields, such as a water-cooled jackets made of black-surfaced aluminum, can effectively carry away heat.

Ventilation and air conditioning. Ventilation, localized air conditioning, and cooled observation booths are commonly used to provide cool working conditions. Cooled observation booths allow workers to cool down after brief periods of intense heat exposure while still allowing them to monitor equipment.

Reducing the humidity. Air conditioning, dehumidification, and elimination of open hot water baths, drains, and leaky steam valves help reduce humidity.

Personal Protection

Ordinary clothing provides some protection from heat radiated by surrounding hot surfaces. Specially designed heat-protective clothing is available. In hot and humid workplaces, light clothing should be worn to allow maximum skin exposure and efficient body cooling by sweat evaporation.

Workers who move back and forth between very hot, dry indoor environments and cold winter outdoor environments find that long underwear moderates the extremes in temperatures.

Eye protection which absorbs radiation is needed when the work involves very hot objects, such as molten metals and hot ovens.

Work that requires the wearing of impermeable clothing presents an added heat burden as the clothing reduces the body's ability to dissipate heat. Under such circumstances, it is often necessary to reduce the threshold limit values of WBGT to levels below those appropriate for workers wearing light clothing.

Heat Acclimatization

The body adapts to a new thermal environment by a process called acclimatization. Complete heat acclimatization generally takes six to seven days, but some individuals may need longer. Loss of acclimatization occurs gradually when a worker is moved permanently away from a hot environment. But a decrease in heat tolerance occurs even after a long weekend. As a result of reduced heat tolerance, it is often not advisable for anyone to work under very hot conditions on the first day of the week.

New employees should acclimatize before assuming a full workload. It is often advisable to assign about half of the normal workload to a new employee on the first day of work. The workload can be gradually increased on subsequent days.

Although well-trained, physically fit workers tolerate heat better than people in poor physical condition, fitness and training do not substitute for acclimatization.

Some medications interfere with acclimatization. For example hypotensives (drugs causing low blood pressure), diuretics, antispasmodics, sedatives, tranquilizers, antidepressants and amphetamines decrease the body's ability to cope with heat. Workers should seek a doctor's advice on the suitability of a medication for them if they work in hot environments.

Consumption of alcohol also interferes with acclimatization.

Prevention

If practical, workers in hot environments should be encouraged to set their own work and rest schedules. Infrequent or irregular tasks, such as emergency repairs of hot process equipment, often result in heat exposure. Experienced workers can often judge heat strain and limit their exposure accordingly. Inexperienced workers may need special attention, as they may continue to work beyond the point at which signs of heat strain appear.

Salt and fluid supplements

A person working in a very hot environment must replace water and salt lost through sweat. On average, about one litre of water each hour is required to replace the fluid loss. Salt tablets may be taken or salt may be added to ample water (about one teaspoon per four litres).

Workers on salt-restricted diets should discuss the need for supplementary salt with a physician.

Emergency action plan

In extreme environments, an emergency plan is needed. The plan should include procedures for providing affected workers with first aid and medical care.

APPENDIX A

Calculation of WBGT Index

The wet bulb globe temperature (WBGT) is calculated by using the following equations.

- For outdoors with direct sun exposure:

$$WBGT = 0.7 \times Temp_{wet\ bulb} + 0.2 \times Temp_{globe} + 0.1 \times Temp_{air}$$

- For indoors or outdoors without direct sun exposure:

$$WBGT = 0.7 \times Temp_{wet\ bulb} + 0.3 \times Temp_{globe}$$

where $Temp_{wet\ bulb}$ = natural wet bulb temperature measured by using a thermometer whose bulb is covered with wet cotton cloth and is cooled by the natural air movement.

$Temp_{globe}$ = temperature measured using a black globe thermometer

$Temp_{air}$ = temperature measured using conventional thermometer,

all temperatures to be expressed in °C.

Example

Workers employed in an outdoor workplace with direct exposure to the sun. Measurement of workplace conditions produced the following results.

$Temp_{wet\ bulb}$ = 24°C
$Temp_{globe}$ = 42°C
$Temp_{air}$ = 40°C

$$WBGT = 0.7 \times 24 + 0.2 \times 42 + 0.1 \times 40 = 29.2°C.$$

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Time-weighted Averaging

When thermal conditions of the workplace fluctuate widely, time-weighted average (TWA) WBGT is used to assess heat exposure.

$$\text{TWA WBGT} = \frac{WBGT_1 \times t_1 + WBGT_2 \times t_2 + ... + WBGT_n \times t_n}{t_1 + t_2 + ... + t_n}$$

where $WBGT_1$, $WBGT_2$, etc. = the wet bulb globe temperatures measured or calculated

t_1, t_2, etc. = the elapsed time spent in the corresponding conditions described by $WBGT_1$, $WBGT_2$, etc. respectively.

Example

Measurement and/or calculation of WBGT during a two-hour job produced the following results.

Exposure duration (hours)	WBGT (°C)
0.5	25
1.0	27
0.5	28

These data would yield the following time-weighted average.

$$\text{TWA WBGT} = \frac{25 \times 0.5 + 27 \times 1.0 + 28 \times 0.5}{0.5 + 1.0 + 0.5} = 26.75°C$$

APPENDIX B

Summary of Control Measures

Method of Control	Action
Engineering controls	
Reduce body heat production	Mechanize tasks.
Stop exposure to radiated heat from hot objects	Insulate hot surfaces. Use reflective shields, aprons, remote controls.
Reduce convective heat gain	Lower air temperature. Increase air speed if air temperature below 35°C. Increase ventilation, provide cool observation booths.
Increase sweat evaporation	Reduce humidity, increase air speed (movement).
Clothing	Wear loose clothing that permits sweat evaporation but stops radiant heat. Use cooled protective clothing for extreme conditions.
Administrative controls	
Acclimatization	Allow sufficient acclimatization period before full work load.
Duration of work	Shorten exposure time, use frequent rest breaks.
Rest area	Provide cool (air-conditioned) rest areas.
Salt and water	Provide cool drinking water with 0.1% salt.
Pace of work	If practical, allow workers to set their own pace of work.
First aid and medical care	Define emergency procedures. Assign one person trained in first aid to each work shift.

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APPENDIX C

Glossary of Terms

Acclimatization - Physiological changes which occur in response to several days of heat exposure and make the body accustomed to a hot environment.

Convection - Process of heat exchange between the body and the surrounding air or fluid as a result of bulk flow of that air or fluid.

Dehydration - Loss or deficiency of water in body tissues caused by sweating, vomiting or diarrhea. Symptoms include excessive thirst, nausea, and exhaustion.

Heat cramps - Painful and often incapacitating cramps in muscles. They are caused by depletion of salt in the body as a result of heavy sweating, and ingestion of water without replacing salt.

Heat exhaustion - Weakness, lassitude, dizziness, visual disturbance, feeling of intense thirst and heat, nausea, vomiting, palpitations, tingling and numbness of extremities after exposure to a hot environment.

Heat hyperpyrexia - Rise in body temperature with moist skin and cerebral dysfunction, caused by exposure to an extremely hot environment.

Heat rash (prickly heat or milliaria) - An itchy rash of small raised red spots on the face, neck, back, chest and thighs caused by a hot and moist environment.

Heat strain - Physiological and behavioural responses of the body as a result of heat exposure.

Heat stroke - Acute illness caused by overexposure to heat. Symptoms are dry, hot skin, high body temperature (usually over 105°F) and cerebral dysfunction.

Heat syncope - Temporary loss of consciousness induced by insufficient flow of blood to the brain. Recovery is normally prompt and without any long-term ill effects.

Metabolic rate - Rate of energy production of the body which varies with the level of activity.

Natural Wet Bulb Temperature - Air temperature measured using a thermometer in which the bulb is covered with wet cotton wick and cooled by the natural movement of air.

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Nausea - The feeling that one is about to vomit as experienced in seasickness.

Prickly Heat - See heat rash.

Radiation (heat) - Transfer of heat between hot and cold bodies without contact between them.

Relative humidity - The ratio of the water vapour content of air to the maximum possible water vapour content of air at the same temperature and air pressure.

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